FORT PROVIDENCE MOOSE SURVEY--

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CHRISTOPHER C. SHANK

DEPARTMENT OF RENEWABLE RESOURCES

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ABSTRACT

Preliminary data suggest that increasing wood bison (Bison bison athabascae) populations in the Mackenzie Bison Sanctuary may be causing a decline in local moose (Alces alces) populations. If this situation is occurring, one would expect current moose population density to be roughly inversely proportional to bison density, and future moose populations to decline as bison numbers increase. We surveyed moose in three study areas (each ca. 1200 km^2) to test the first hypothesis and to establish baseline moose densities against which future surveys could be compared.

The Mills Lake study area is characterized by low bison density whereas the Falaise Lake study area is a high bison density area. The Mink Lake study area is intermediate. Moose densities were estimated to be about 0.13·km^{-2} at Mills Lake, 0.25·km^{-2} at Mink Lake, and 0.12·km^{-2} at Falaise Lake.

Moose densities did not vary inversely with bison densities as hypothesized. Current moose densities are 2-3 times higher than reported from surveys in 1965 and 1971. The earlier surveys used a different technique but, nevertheless, one must question whether the putative moose declines have actually occurred. Analysis suggests that a future survey using the same technique and effort should be able to detect 30-50% declines with 70-90% certainty.

These results do not disprove the hypothesis that bison are negatively impacting moose populations, but they provide no support for the hypothesis.

TABLE OF CONTENTS

ABSTRACT ii

TABLE OF CONTENTS iii

LIST OF FIGURES iv

LIST OF TABLES v

INTRODUCTION 1

METHODS 2

RESULTS 5

DISCUSSION 7

ACKNOWLEDGEMENTS 11

PERSONAL COMMUNICATIONS 12

LITERATURE CITED 13

APPENDIX A. LAT/LONGS FOR CORNERS OF MOOSE SURVEY UNITS 27

APPENDIX B. ANIMALS SEEN ON RECONNAISSANCE 31

APPENDIX C. OBSERVATIONS MADE DURING MILLS LAKE SURVEY 38

APPENDIX D. OBSERVATIONS MADE DURING MINK LAKE SURVEY 40

LIST OF FIGURES

Figure 1. Survey units in the Mills Lake study area 14

Figure 2. Survey units in the Mink Lake study area 15

Figure 3. Survey units in the Falaise Lake study area 16

Figure 4. Approximate variances required of future surveys in the Mills Lake study area to detect population declines of various pro-portions with varying degrees of likelihood of detecting the decline 17

Figure 5. Approximate variances required of future surveys in the Mink Lake study area to detect population declines of various pro-portions with varying degrees of likelihood of detecting the decline 18

LIST OF TABLES

Table 1.	Areas and stratification of survey units in the three study areas	19
Table 2.	Summary of reconnaissance flights	20
Table 3.	Summary of effort, areas, and moose seen on each of the Mills Lake survey units	21
Table 4.	Summary of effort, area, and moose seen on each of the Mink Lake survey units	22
Table 5.	Survey results for Mills Lake	23
Table 6.	Survey results for Mink Lake	24
Table 7.	Summary of age-sex data for the Mills and Mink Lake study areas	25
Table 8.	Approximate coefficients of variation required of future surveys to detect population declines of various proportions with varying degrees of probabilities of making Type I and Type II errors	26

INTRODUCTION

In August 1963, 20 wood bison (Bison bison athabascae) were introduced near Fort Providence. The population grew rapidly and now numbers close to 2300 (C. Gates, pers. comm.). In the 1960's, bison range was restricted to Falaise Lake but expanded to Mink Lake by 1980 and Mills Lake by 1986 (Gates and Larter 1990: Figs. 1 and 4). There is an indication that the local moose population declined coincidentally with this increase in bison density and range. In 1965, an aerial transect survey located one moose every 21 km flown. In 1971, the figure was one moose every 18 km. However, a similar survey in 1987 located only one moose in 1075 km flown (Gates and Larter 1990). Gates and Larter (1990) suggest that increased bison numbers may have resulted in a functional response in the wolf population leading to a higher wolf:moose ratio and increased rates of moose predation. Local peoples have suggested that moose do not like either the noise or smell of bison and consequently avoid them.

There were two reasons for undertaking this survey. The first was to provide baseline data on moose numbers and distribution using a survey design which could be repeated to establish whether moose populations change through time. The second was to test the hypothesis that moose populations are currently inversely related to bison numbers, as would be expected if moose populations decline as bison numbers increase.

METHODS

Three study areas were chosen to reflect differing densities of bison as determined by Gates and Larter (1990). The Mills Lake area was chosen for its low bison density, Mink Lake for moderate bison density, and Falaise Lake to represent high density. It was considered important to have three areas to avoid difficulties with pseudoreplication (Hurlbert 1978).

With the money available, it was determined that the three areas could each be no larger than 1200 km^2. The boundaries of the study areas were chosen to fall within the limits of existing Landsat images. Following Gasaway et al. (1986), survey units were defined to encompass about 30 km^2. Because we used Global Positioning System (GPS) for navigating during the survey, we drew the survey units with orthogonal boundaries running east-west and north-south (Figures 1 - 3). Survey units were delineated by reference to enhanced Landsat images and, to the extent possible, each contained predominantly one habitat type. Appendix A presents the latitudes and longitudes of survey unit corners. Areas were determined by AutoCad and are presented in Table 1.

Survey techniques followed the methods detailed by Gasaway et al. (1986). A Cessna 185, equipped with GPS, was used for reconnaissance on November 6 - 8. A total of 14.7 hours was flown. Two observers (Bruno Croft and Walter Landry) sat in the back seats and the front passenger (Chris Shank) navigated and recorded data. Altitude was about 250 feet (80 m) and speed averaged 100 mph (160 kph). Between 5 and 9 minutes were spent in each survey unit (Table 2). A variety of navigation techniques was used. The most effective was to employ long transects navigated by GPS going through a line of survey units, a turn, and a return through the same survey units along a parallel line several km from the first. Entry and exit times for each unit was recorded. Snow conditions were not perfect for the reconnaissance with the latest snow being about 10 days earlier.

Tracks and numbers of moose and bison were counted. If no moose or moose tracks were seen, the survey unit was classified into the Low Stratum. If tracks were seen, the unit was classified as Medium. If moose were observed, the unit was classified as High.

Only the Mink and Mills Lake study areas were surveyed by helicopter. It was decided before the survey commenced that moose densities at Falaise Lake would probably be too low to warrant the expense of a helicopter survey. The survey was done using two Bell 206B helicopters simultaneously on November 11 - 14. Survey units were chosen using a random number generating program. Three survey units in each of the three strata in both study areas were initially surveyed in a sequence designed to minimize ferry costs. Transects were flown at .5 km intervals with waypoints at the far edge of the survey unit programmed into the GPS unit. By pacing off 250 m from a drum, it was confirmed that a 250 m strip was easily observed on both sides of the aircraft with considerable overlap thereby ensuring complete coverage of the survey unit. Persons in the two rear seats observed while the front seat passenger navigated and observed. Altitude varied from 150 feet (50 m) to 250 feet (80 m). Speed was approximately 80 kph over dense trees and 110 kph over open ground. All moose and bison were examined closely and the GPS location recorded. Including the ferry from and to Yellowknife, the total number of helicopter hours flown was 45.9.

Four drums of fuel were cached at the influx of the Horn River into Mink Lake and four drums were cached on Raspberry Point. This allowed >6 hours of flying time without having to return to town to re-fuel. A contract was given out to local residents for retrieval of the empty drums.

Analysis of the Mills and Mink Lake data was by the BASIC program MOOSEPOP (Reed 1989). No "sightability correction factor" (SCF) (Gasaway et al. 1986) was calculated for two

reasons. First, Gasaway et al. suggest that an increased effort is not warranted if the density of moose is less than $1 \cdot mi^{-2}(.37 \cdot km^{-2})$ which was achieved in only 6 of the 28 units surveyed. Secondly, for the purposes of this survey, absolute numbers of moose are not as important as are relative numbers between areas and through time. The average SCF for early winter cited in Gasaway et al.'s (1986: 35) is 1.13. Our estimates are therefore likely to be about 13% too low.

We did not survey the Falaise Lake study area but based our estimate on the reconnaissance flight. For the Mills and Mink Lake areas, a correction factor was calculated relating the number of moose seen in the reconnaissance to the number estimated during the survey. This factor was used to convert the number of moose seen on the Falaise Lake reconnaissance to a total number present.

RESULTS

Appendix B presents a list of observations made during the reconnaissance. For the 36 Mills Lake survey units, 16 were classified as Low, 11 as Medium, and 9 as High. Of the 36 Mink Lake survey units, 8 were classified as Low, 13 as Medium, and 15 as High (Tables 1 and 2). An average time of between 5.4 and 7.7 minutes were flown in each survey unit (Table 2). More time was flown in the Mills Lake study area because we were still perfecting our techniques. As expected, most bison were seen at Falaise Lake and the fewest at Mills Lake with Mink Lake falling in-between (Table 2). Contrary to our expectations, the number of moose seen on reconnaissance did not vary inversely with the number of bison (Table 1). Approximately the same number of moose were seen at Falaise Lake as at Mills Lake (18 vs. 19) whereas more than twice as many moose were found in the Mink Lake study area, the medium bison zone.

Appendix C presents a list of observations made during the survey. Tables 3 and 4 summarize these data for Mills and Mink Lakes respectively. At Mills Lake, the average time needed to survey a unit was 62.3±11.9 minutes. In the Mink Lake study area, the average time spent in a survey unit was 61.5±11.8 minutes. Fifteen survey units, representing 41% of the total area, were surveyed in the Mills Lake study area. Because of a more favourable variance, only 13 units, representing 37% of the total area, were surveyed at Mink Lake.

Tables 5 and 6 summarize the survey results. The population estimate for the Mills Lake study area is 140±27 representing a density of $0.12 \cdot km^{-2}$. The coefficient of variation is 19.19%. Correcting for sightability (SCF = 1.13), the actual number of moose at Mills Lake is 158 or .13

moose·km^{-2}. The population estimate for the Mink Lake study area is 264±44 representing a density of 0.22 moose per square kilometre. The coefficient of variation is 16.68%. Correcting for sightability yields an estimated population of 298 or .25 moose·km^{-2}.

The correction factor representing the proportion of the population estimate seen during the reconnaissance was 0.1357 for Mills Lake and 0.1629 for Mink Lake, or an average of 0.1493. Using this correction factor, the 18 moose seen on reconnaissance in the Falaise Lake study area represents a population estimate of about 121 moose or a density of 0.11 moose per square kilometre. Correcting for sightability, the estimate is 137 or .12 moose·km^{-2}. The density estimate is nearly identical to the Mills Lake density. The Falaise Lake estimate is rough (i.e., the accuracy is questionable) and lacks an estimate of statistical precision, but it does provide at least a qualitative idea of the number of moose in the area.

A potential bias is that the number of moose seen was influenced by the search effort expended on the survey unit. The correlation between number of moose and minutes of search per km^2 was R=0.66 for the Mills Lake study area which is statistically significant (p = .007). However, if the outlier point representing Survey Unit 31 is removed, the R value declines to 0.42 which is not statistically significant (p = .138). It is thought that this trend does not reflect a tendency for more intensive search to return more moose but, in fact, the opposite in which more moose found entails more circling to age and sex the animals. At Mink Lake, there was no relationship between search effort and moose seen (R= -0.05, p = .871).

Table 7 presents an analysis of age and sex ratios. The most striking difference between the study areas is the greater proportion of cows observed to be without calves at Mills Lake (60%) relative to at Mink Lake (28%). The proportion of cows with twins was similar in both areas at 3-

4%.

Caribou (Rangifer tarandus) were sighted on two occasions during the Falaise Lake reconnaissance (Appendix B). We saw six caribou in Survey Unit 1 and two caribou in Survey Unit 26. Two white-tailed deer (Odocoileus virginianus) were sighted during the survey in Mills Lake Survey Unit 10. One wolf (Canis lupus) was seen on Mills Lake Survey Unit 24. A pack of 9 wolves was observed killing a B2 bison bull in Mink Lake Survey Unit 34 (61°50.4'N, 117°29.9'W). The bull had crashed through thin ice along the reed-covered lake margin. As well, we saw numerous red foxes (Vulpes fulva), porcupines (Erethizon dorsatum), and marten (Martes americana).

DISCUSSION

The most significant disappointment of the survey was the failure of the Mills Lake reconnaissance to accurately classify survey units into strata. The large number of moose seen in survey units 8 and 31, both classified as Low, played havoc with the Mills Lake population estimates. The stratum density estimates varied inversely to expectations from the reconnaissance (Table 5). The variance of the population estimate made without stratification is 768.2 (CV = 19.4) compared to 722.4 (CV = 19.2) with stratification. The reconnaissance contributed little to a better result.

It is difficult to recommend how to do a better reconnaissance in future surveys. The problem lies in the low density of moose entailing the use of tenuous clues to decide upon relative density. At low moose densities (i.e., $0.1 \cdot km^{-2}$), a judgement should be made whether to put greater effort into

reconnaissance flights (ca. 15 min/survey unit) or into a higher intensity but unstratified survey thereby saving the cost of reconnaissance. Reconnaissance flights done directly after a new snowfall would certainly be more accurate.

Moose densities did not differ between areas as expected. We expected an inverse relationship between moose and bison densities. In fact, the high and low bison density areas (Falaise and Mills Lakes respectively) had similar moose densities which were about half those of the medium bison density area, Mink Lake. There are at least three plausible explanations.

1) Bison are affecting moose populations but the habitat at Mills Lake is unsuitable thereby counteracting the advantage gained from low bison numbers.
2) Bison are affecting moose numbers but hunting pressure has reduced population density at Mills Lake thereby counteracting the advantages of low bison numbers.
3) Bison have no effect on moose numbers and the moose populations in the three areas are responding to local conditions of habitat, predation, and harvest.

Hypothesis 1 can be tested by determining whether there are differences in the proportion of habitat types in the three areas. Once a Landsat classification is completed for the general area, an analysis can be made of habitat and density.

Hypothesis 2 can be approached by getting an idea about the magnitude and location of harvest in the Mills Lake study area. If the community of Fort Providence is interested, a small harvest study might be conducted.

Hypothesis 3 can be tested by establishing trends in moose and bison numbers in the three

study areas to determine if the relationships are in synchrony.

Graf (n.d.) has summarized moose population density estimates from recent surveys done in the Northwest Territories. Densities range from .03 to .15 moose·km^{-2}. The Mills and Falaise Lake study areas are near the upper end of observed moose densities in the Northwest Territories whereas the Mink Lake area has the highest density yet recorded. Gates and Larter (1990) cite moose densities in the Mackenzie Bison Sanctuary of 0.059·km^{-2} in 1965 and 0.066·km^{-2} in 1971.

The population estimates presented here are not exact measures of population size. Therefore, statistical procedures must be employed to determine how likely it is that estimates from future surveys represent an actual change in population size. Two types of error must be considered. A Type I error occurs when one concludes that a population change occurred when, in fact, it did not. The largest acceptable risk of making a Type I error is α. A Type II error occurs when one falsely concludes that there has been no population change when, in fact, there has been. The largest acceptable risk of making a Type II error is β or the "power" of the test. In this case, if a Type I error is made, false fears will have been raised about the decline of moose populations. If, however, a Type II error is made, bison management programs will fail to take into account the negative effects of bison on moose populations. These mistakes seem equally undesirable so α and β have been set as equivalents in the following analysis.

Comparing two population estimates is done by the Student's t-test. Gasaway et al. (1986:66) provide a technique for back-calculating the variance that will be required in the second survey to provide significant results depending upon the variance of the first estimate, the magnitude of population change, and of acceptable levels of α and β. Figures 4 and 5 show, for Mills and Mink Lakes respectively, approximate variances required in future surveys to detect declines of 20%, 30%,

40%, and 50%. Table 8 translates these variances into approximate coefficients of variation required in the future surveys.

Table 8 shows that for Mills Lake, it should be feasible to pick up a decline of 30-50% with a likelihood of 70-80%. A decline of < 50% will not be detected with a certainty > 90%. Table 8 indicates that for Mink Lake the situation is somewhat better. With a very concerted and expensive effort, a 50% decline should be detected with 90% certainty or a 20% decline with 70% certainty. There should be little difficulty in picking up a 40% decline with 80% certainty.

The calf to adult cow ratio seen at Mink Lake was nearly twice as high as at Mills Lake. The Mink Lake calf/cow ratio is as high as ever reported in the Northwest Territories whereas the Mills Lake calf/cow ratio is near the lower limits (Graf n.d.:13). This suggests quite different survivorships to six months of age. We have no explanation for this discrepancy unless Fort Providence hunters are targeting calves and leaving the cows. The twinning rate in both study areas (ca. 3%) was much lower than reported from other portions of the NWT (10-50%) (Graf n.d.:13).

In summary, no evidence was found to support the contention that increasing bison numbers are associated with a decline in moose populations. Moose density estimates calculated from the 1965 and 1971 surveys were one-half to one-third of those documented here although the techniques were not the same. As well, those study areas with larger bison populations did not have fewer moose. These findings do not disprove the hypothesis that increasing bison populations lead to declining moose numbers, but they provide no support for the idea.

ACKNOWLEDGEMENTS

I should like to thank the survey crew (Walter Landry, Allen Bouvier, Mika Sutherland, Laurie Buckland, Bruno Croft) for their keen eyes, good humour, and enthusiasm for the project. Air Providence pilot Ted Molesky put up with many contradictory requests as we learned how best to fly the reconnaissance. Aero Arctic pilots Kevin Faddegon and Randy Maszaros were good company and are fine pilots. Evelyn Krutko, the Renewable Resources Officer in Fort Providence allowed us to stay in the lab and provided us with a vehicle. Mika Sutherland drafted the figures and corrected the manuscript's many errors.

PERSONAL COMMUNICATIONS

Gates, C.C. Bison Ecologist, Department of Renewable Resources, Government of the N.W.T., Yellowknife, NWT

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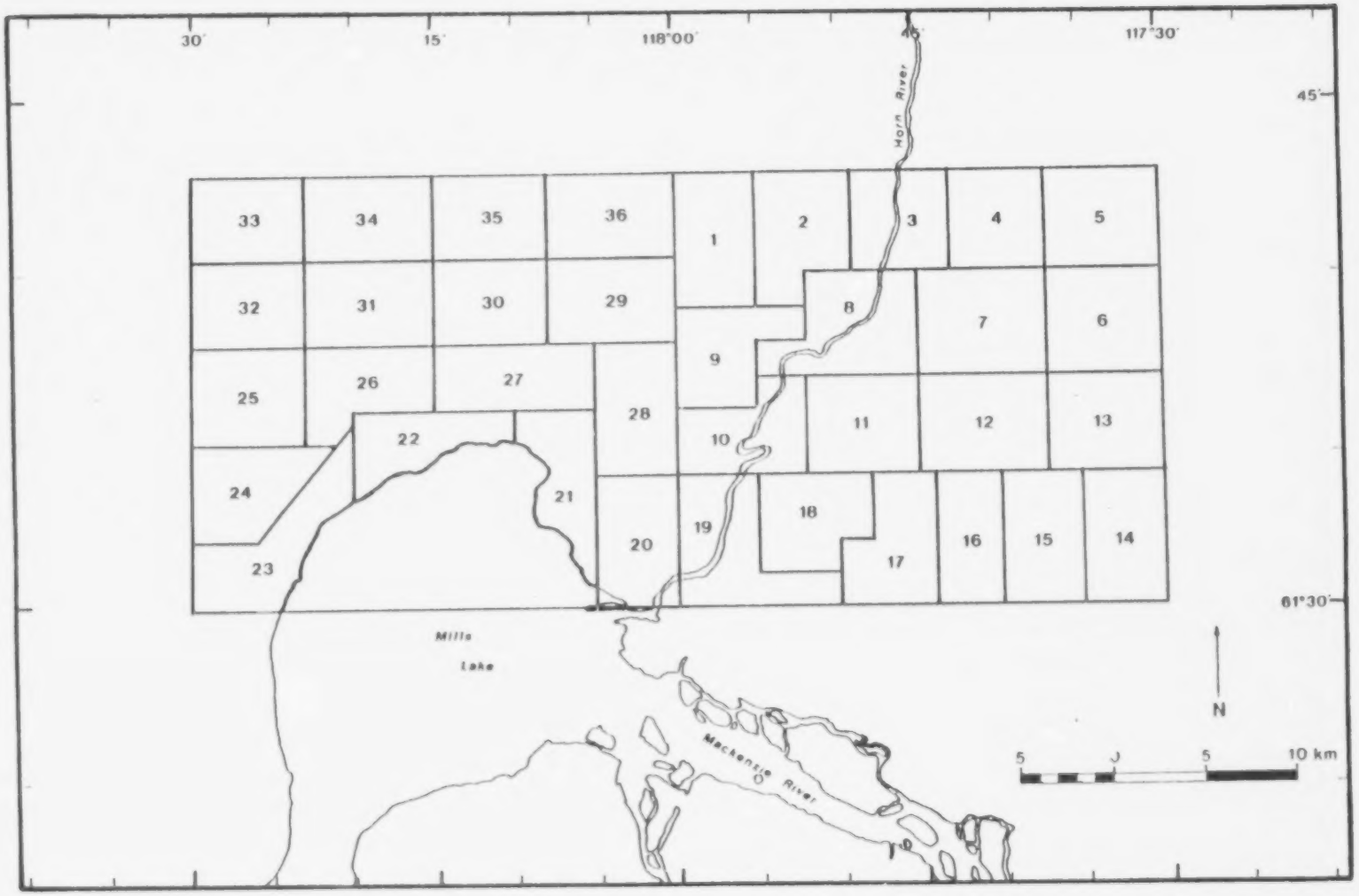

Figure 1. Survey units in hte Mills Lake study area.

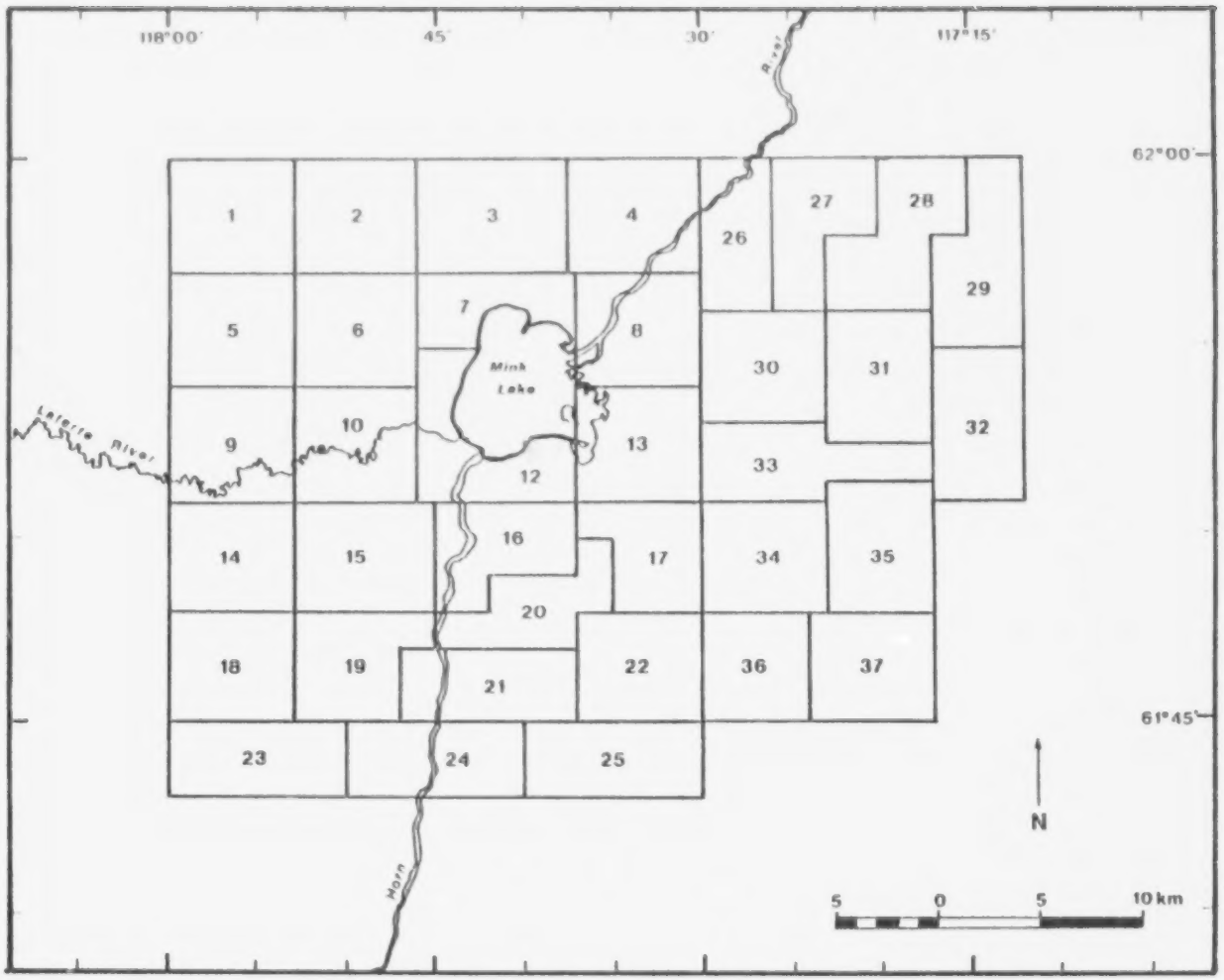

Figure 2. Survey units in the Mink Lake study area.

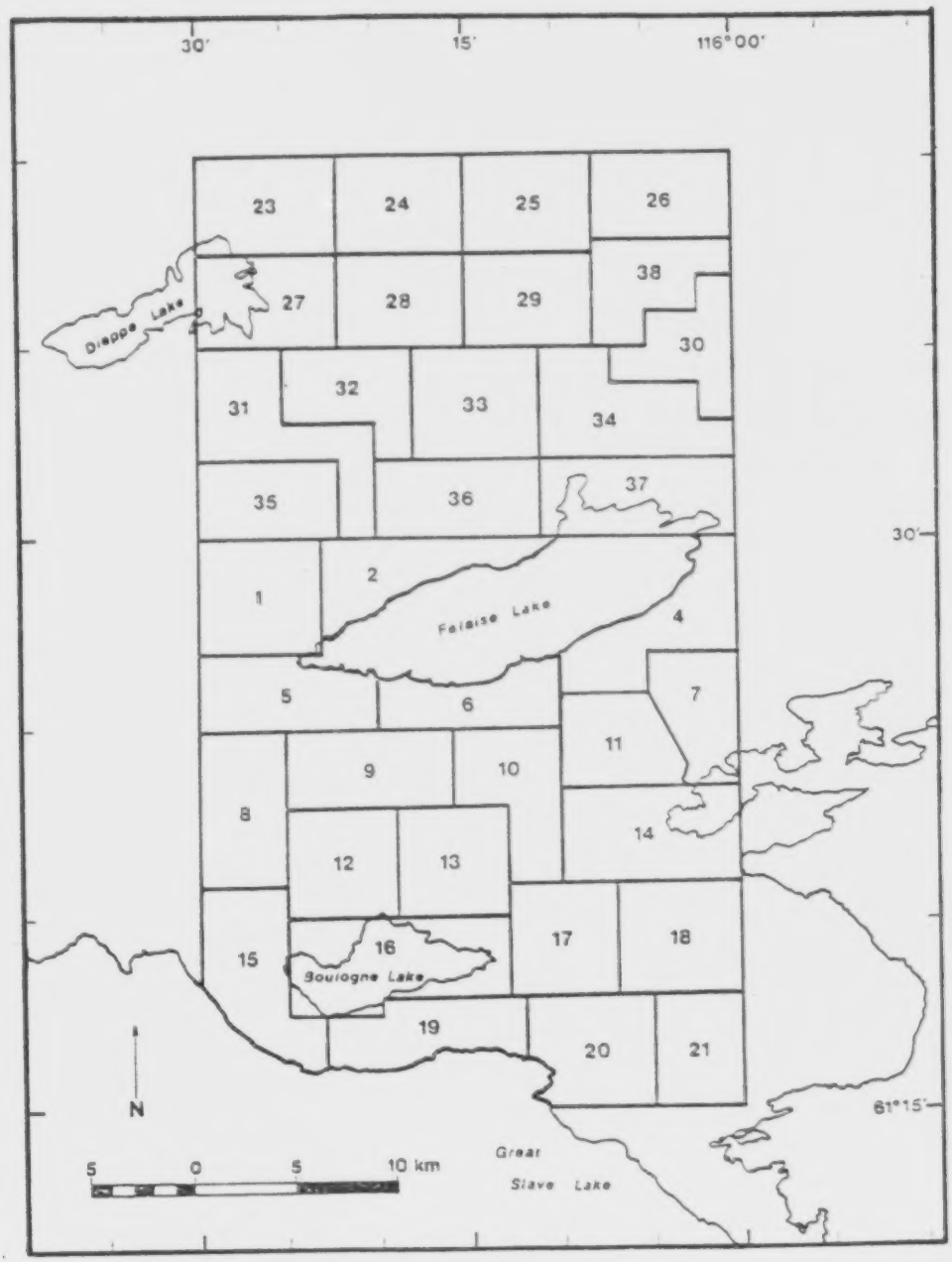

Figure 3. Survey units in the Falise Lake study area.

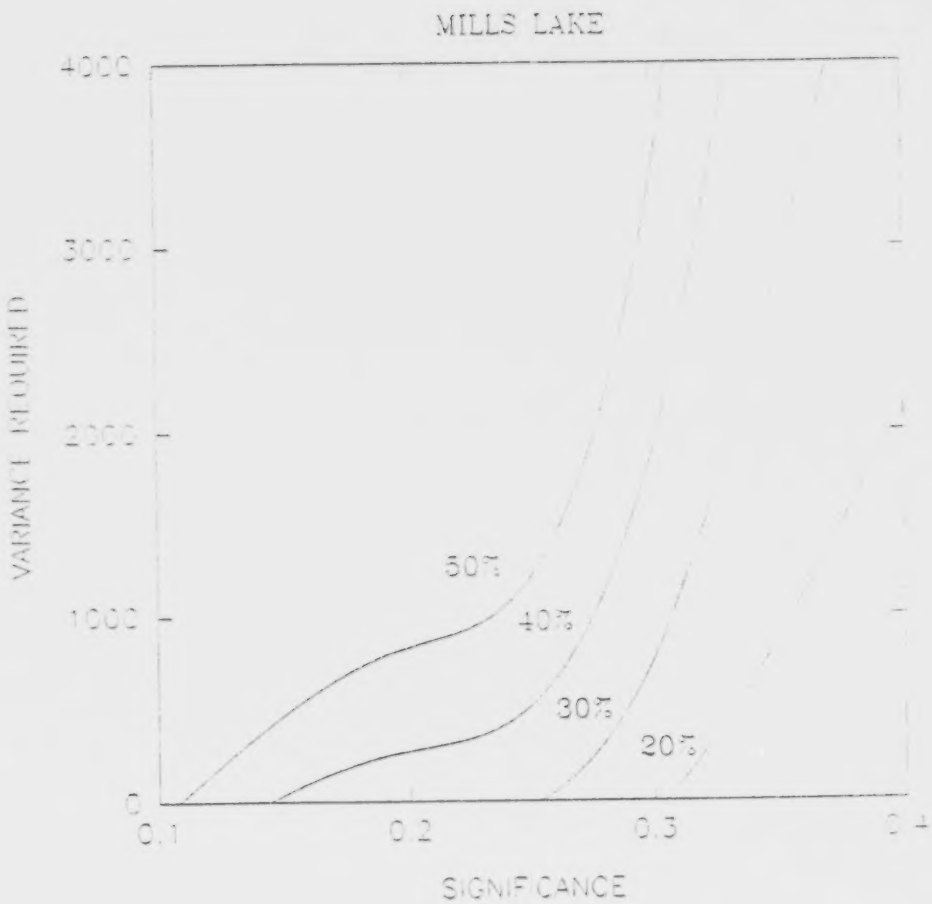

Figure 4. Approximate variances required of future surveys in the Mills Lake study area to detect population declines of various propostions with varying degrees of likelihood of detecting a decline.

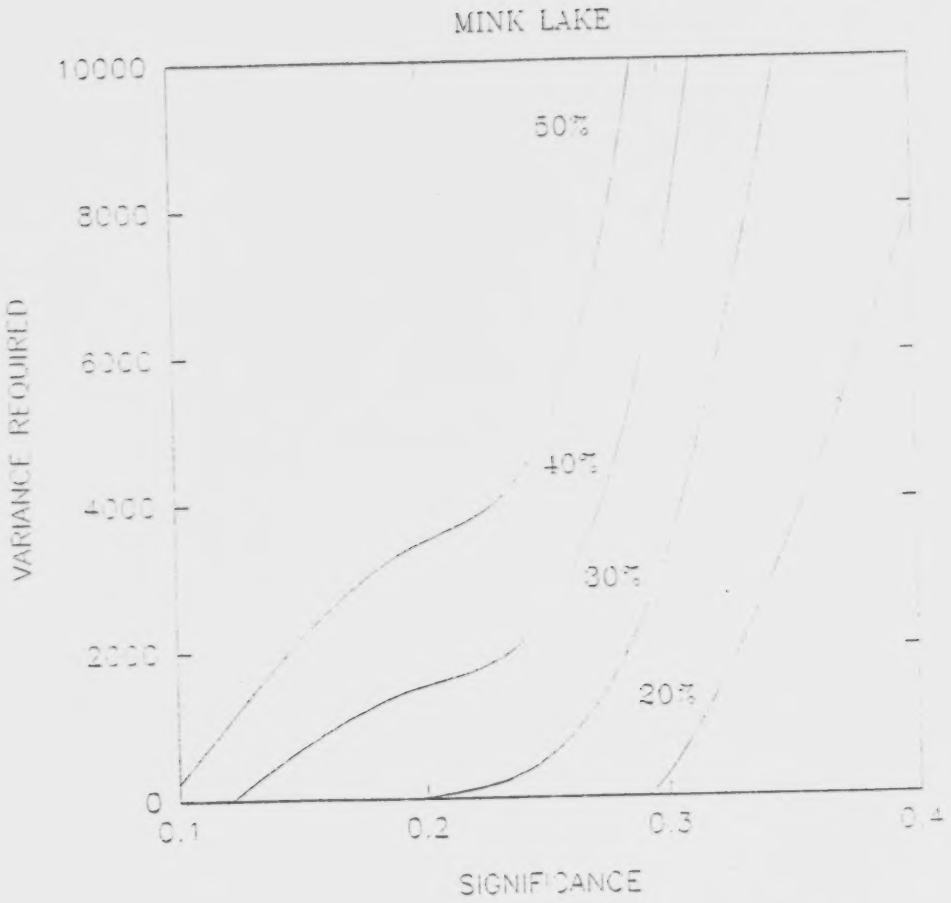

Figure 5. Approximate variances required of future surveys in the Mink Lake study area to detect popualation declines of various propostions with varying degrees of likelihood of detecting the decline.

Table 1. Areas and stratification of survey units in the three study areas.

SU	MILLS LAKE AREA (KM^2)	STRATUM	MINK LAKE AREA (KM^2)	STRATUM	FALAISE LAKE AREA (KM^2)
1	32.24	H	33.94	H	35.22
2	33.76	L	34.25	H	27.59
3	29.03	M	39.63	M	--
4	29.03	M	37.69	L	31.46
5	34.50	H	33.79	H	30.19
6	34.32	H	33.99	M	23.71
7	39.22	L	24.44	M	23.43
8	39.23	L	33.87	M	32.17
9	29.33	H	33.82	H	28.65
10	31.19	M	34.19	H	29.04
11	34.02	H	33.19	L	26.16
12	39.42	H	-	-	30.32
13	34.25	M	33.82	H	29.72
14	32.71	L	34.41	L	40.97
15	33.45	L	39.23	L	39.00
16	26.67	L	30.70	L	40.46
17	32.60	L	27.48	H	27.42
18	31.11	H	33.87	M	31.43
19	40.94	M	32.39	H	32.71
20	32.96	H	27.69	L	36.44
21	34.06	M	32.84	M	27.41
22	30.16	L	33.83	L	--
23	35.99	M	32.05	M	32.86
24	33.02	L	31.89	H	28.53
25	34.37	L	32.19	M	29.16
26	30.69	L	26.00	L	29.36
27	33.07	M	28.86	M	32.40
28	32.79	L	35.64	M	28.25
29	32.46	M	33.41	M	28.54
30	28.33	M	33.91	H	26.02
31	32.52	L	34.04	H	39.16
32	28.38	L	32.29	H	26.29
33	28.60	L	33.82	H	34.82
34	32.71	H	34.15	H	39.83
35	28.49	M	34.05	H	26.40
36	32.78	L	28.93	M	29.67
37	--	-	33.98	M	35.95
38	--	-	--	-	24.12
Σ	1178.40		1184.27		1114.86
$\bar{x}$	32.73		32.90		30.97
SD	3.33		3.17		4.84

Table 2. Summary of reconnaissance flights.

	MILLS LAKE	MINK LAKE	FALAISE L.
SU'S IN LOW STRATUM	16	8	-
SU'S IN MEDIUM STRATUM	11	13	-
SU'S IN HIGH STRATUM	9	15	-
MEAN TIME/SU	7.7	5.7	5.4
NUMBER MOOSE	19	43	18
NUMBER BISON	42	ca. 160	ca. 740

Table 3. Summary of effort, areas, and moose seen on each of the Mills Lake survey units.

MILLS LAKE

STRATUM	SURVEY UNIT	DATE	NUMBER MOOSE	AREA (KM^2)	EFFORT (MIN/KM^2)
LOW	16	91.11.11	0	26.67	1.57
	8	91.11.12	9	39.23	2.06
	31	91.11.13	15	32.52	2.50
	33	91.11.13	0	28.60	1.64
	17	91.11.14	5	32.60	2.27
	2	91.11.14	0	33.76	1.72
	25	91.11.14	5	34.37	1.60
	14	91.11.14	2	32.71	1.62
	TOTAL		36	260.46	1.87±.36
MEDIUM	27	91.11.12	7	33.07	1.97
	10	91.11.12	1	31.19	2.15
	35	91.11.13	2	28.49	1.86
	TOTAL		10	92.75	1.99±.15
HIGH	5	91.11.12	3	34.50	2.03
	18	91.11.12	2	31.11	1.99
	11	91.11.13	4	34.02	2.09
	34	91.11.13	4	32.71	1.68
	TOTAL		13	132.34	1.95±.18
GRAND TOTAL			59	485.55	1.92±.28

Table 4. Summary of effort, area, and moose seen on each of the Mink Lake survey units.

MINK LAKE

STRATUM	SURVEY UNIT	DATE	NUMBER MOOSE	AREA (KM^2)	EFFORT (MIN/KM^2)
LOW	20	91.11.12.	3	27.69	2.13
	4	91.11.12.	3	37.69	1.78
	16	91.11.12.	0	30.70	2.48
	TOTAL		6	96.08	2.13±.25
MEDIUM	37	91.11.11.	13	33.98	1.53
	28	91.11.12.	6	35.64	2.36
	6	91.11.13	0	33.99	1.21
	3	91.11.13.	5	39.63	1.51
	29	91.11.14.	5	33.41	1.98
	TOTAL		29	176.65	1.72±.45
HIGH	35	91.11.11.	17	34.05	2.11
	5	91.11.13	0	33.79	1.57
	1	91.11.13.	16	33.94	1.62
	32	91.11.13.	16	32.29	1.92
	34	91.11.14.	11	34.15	1.35
	TOTAL		60	168.22	1.71±.30
GRAND TOTAL			95	440.95	1.81±.39

Table 5. Survey results for Mills Lake.

	LOW	MEDIUM	HIGH	TOTAL
NUMBER OF SU'S	16	11	9	36
TOTAL AREA	521.00	357.40	300.60	1179.0
SU'S SURVEYED	8	3	4	15
AREA SURVEYED (KM^2)	260.46	92.75	132.34	485.55
MOOSE SEEN	36	10	13	59
DENSITY (PER KM^2)	0.14	0.11	0.10	0.12
POPULATION ESTIMATE	72.0	38.5	29.5	140.1
VARIANCE	413.41	300.11	8.86	722.38
DEGREES OF FREEDOM	7	2	3	8
COEFFICIENT OF VARIATION	28.24	45.0	10.09	19.19

Table 6. Survey results for Mink Lake.

	LOW	MEDIUM	HIGH	TOTAL
NUMBER OF SU'S	8	13	15	36
TOTAL AREA (KM^2)	262.70	423.70	497.80	1184.20
SU'S SURVEYED	3	5	5	13
AREA SURVEYED (KM^2)	96.08	176.65	168.22	440.85
MOOSE SEEN	6	29	60	95
DENSITY (PER KM^2)	0.06	0.16	0.36	0.22
POPULATION ESTIMATE	16.4	69.6	177.6	263.5
VARIANCE	40.01	392.71	1499.50	1932.22
DEGREES OF FREEDOM	2	4	4	6
COEFFICIENT OF VARIATION	38.57	28.47	21.80	16.68

Table 7. Summary of age-sex data for the Mills and Mink Lake study areas.

NUMBER OR RATIO	MILLS LAKE	MINK LAKE
TOTAL MOOSE SEEN	59	95
TOTAL COWS SEEN	26	34
TOTAL BULLS SEEN	22	39
TOTAL CALVES SEEN	11	22
LONE COWS	16	13
COWS WITH 1 CALF	9	20
COWS WITH 2 CALVES	1	1
YEARLING BULLS	3	5
MEDIUM BULLS	9	8
LARGE BULLS	10	26
BULLS/TOTAL MOOSE	.3826	.4133
COWS*/TOTAL MOOSE	.3985	.3044
CALVES/TOTAL MOOSE	.1722	.2292
YEARLINGS**/TOTAL MOOSE	.0934	.0532
CALVES/ADULT COWS*	.4323	.7592
BULLS/ADULT COWS*	.9601	1.3577
LONE COWS***/ADULT COWS*	.6036	.2840
COWS + 1 CALF/ADULT COWS*	.3606	.6791
COWS WITH 2 CALVES/ADULT COWS*	.0358	.0369
YEARLING BULLS/TOTAL BULLS	.1221	.1287
MEDIUM BULLS/TOTAL BULLS	.4447	.2122
LARGE BULLS/TOTAL BULLS	.4332	.6591

* Adult cows are estimated as total cows minus yearling bulls with the expectation that the yearling sex ratio is equal.

** Yearlings are estimated as twice the number of male yearlings.

*** Lone cows are estimated as total cows minus yearling bulls.

Table 8. Approximate coefficients of variation required of future surveys to detect population declines of various proportions with varying degrees of likelihood of detecting the decline (power of the test = α) and, having detected the decline, being certain that it is real (β). For ease of presentation, α and β are made equal.

α AND β SIGN.	50% 1991 NUMBERS	60% 1991 NUMBERS	70% 1991 NUMBERS	80% 1991 NUMBERS
	MILLS LAKE			
0.10	< 0.0	< 0.0	< 0.0	< 0.0
0.20	41.0	19.1	< 0.0	< 0.0
0.30	82.9	51.9	27.1	< 0.0
	MINK LAKE			
0.10	11.9	< 0.0	< 0.0	< 0.0
0.20	44.6	24.3	< 0.0	< 0.0
0.30	> 75	54.3	31.2	8.3

APPENDIX A. LAT/LONGS FOR CORNERS OF MOOSE SURVEY UNITS

Mills Lake

Survey Unit 1 6143 11800, 6143 11755, 6139 11800, 6139 11755
Survey Unit 2 6143 11755, 6143 11749, 6139 11755, 6139 11752, 6140 11752, 6140 11749
Survey Unit 3 6143 11749, 6143 11743, 6140 11749, 6140 11743
Survey Unit 4 6143 11743, 6143 11737, 6140 11743, 6140 11737
Survey Unit 5 6143 11737, 6143 11730, 6140 11737, 6140 11730
Survey Unit 6 6140 11737, 6140 11730, 6137 11737, 6137 11730
Survey Unit 7 6140 11745, 6140 11737, 6137 11745, 6137 11737
Survey Unit 8 6140 11752, 6140 11745, 6138 11755, 6138 11752, 6137 11755, 6137 11745
Survey Unit 9 6139 11800, 6139 11752, 6136 11800, 6136 11755, 6138 11755, 6138 11752
Survey Unit 10 6136 11800, 6136 11755, 6137 11755, 6137 11752, 6134 11800, 6134 11752
Survey Unit 11 6137 11752, 6136 11745, 6134 11745, 6134 11752
Survey Unit 12 6137 11745, 6137 11737, 6134 11745, 6134 11737
Survey Unit 13 6137 11737, 6137 11730, 6134 11737, 6134 11730
Survey Unit 14 6134 11735, 6134 11730, 6130 11735, 6130 11730
Survey Unit 15 6134 11740, 6134 11735, 6130 11740, 6130 11735
Survey Unit 16 6134 11744, 6134 11740, 6130 11744, 6130 11740
Survey Unit 17 6134 11748, 6134 11744, 6132 11750, 6132 11748, 6130 11750, 6130 11744
Survey Unit 18 6134 11755, 6134 11748, 6132 11750, 6132 11748, 6131 11755, 6131 11750
Survey Unit 19 6134 11800, 6134 11755, 6130 11800, 6130 11750, 6131 11755, 6131 11750
Survey Unit 20 6134 11805, 6134 11800, 6130 11805, 6130 11800
Survey Unit 21 6136 11810, 6136 11805, 6130 11805, 6130 11807.13, thence along shore of Mills Lake to 6134.7 11810
Survey Unit 22 6136 11820, 6136 11810, 6133.1 11820, thence along the shore of Mills Lake to 6134.7 11810
Survey Unit 23 6132 11830, 6132 11826, along cutline to 6135.6 11820, 6133.1 11820, thence along shore of Mills Lake to 6130 11824.5, 6130 11830
Survey Unit 24 6135 11830, 6135 11821, thence along the cutline to 6132 11826, 6132 11830
Survey Unit 25 6138 11830, 6138 11823, 6135 11830, 6135 11823
Survey Unit 26 6138 11823, 6138 11815, 6136 11815, 6136 11820, 6135.6 11820, 6135 11821, 6135 11823
Survey Unit 27 6138 11815, 6138 11805, 6136 11815, 6136 11805
Survey Unit 28 6138 11805, 6138 11800, 6134 11805, 6134 11800
Survey Unit 29 6140.5 11808, 6140.5 11800, 6138 11808, 6138 11800
Survey Unit 30 6140.5 11815, 6140.5 11808, 6138 11815, 6138 11808
Survey Unit 31 6140.5 11823, 6140.5 11815, 6138 11823, 6138 11815
Survey Unit 32 6140.5 11830, 6140.5 11823, 6138 11830, 6138 11823
Survey Unit 33 6143 11830, 6143 11823, 6140.5 11823, 6140.5 11830
Survey Unit 34 6143 11823, 6143 11815, 6140.5 11823, 6140.5 11815
Survey Unit 35 6143 11815, 6143 11808, 6140.5 11815, 6140.5 11808
Survey Unit 36 6143 11808, 6143 11800, 6140.5 11808, 6140.5 11800

Mink Lake

Survey Unit 1 6200 11800, 6200 11753, 6157 11800, 6157 11753
Survey Unit 2 6200 11753, 6200 11746, 6157 11753, 6157 11746
Survey Unit 3 6200 11746, 6200 11737.5, 6157 11746, 6157 11737.5
Survey Unit 4 6200 11737.5, 6200 11730, 6157 11737.5, 6157 11730
Survey Unit 5 6157 11800, 6157 11753, 6154 11800, 6154 11753
Survey Unit 6 6157 11753, 6157 11746, 6154 11753, 6154 11746
Survey Unit 7 6157 11746, 6157 11737, 6155 11746, 6155 11737
Survey Unit 8 6157 11737, 6157 11730, 6154 11737, 6154 11730
Survey Unit 9 6154 11800, 6154 11753, 6151 11800, 6151 11753
Survey Unit 10 6154 11753, 6154 11746, 6151 11753, 6151 11746
Survey Unit 11 - -
Survey Unit 12 6155 11746, 6151 11746, 6151 11737, 6152.6 11737, thence along the W shore of Mink Lake to 6155 11742.2
Survey Unit 13 6154 11737, 6154 11730, 6151 11737, 6151 11730
Survey Unit 14 6151 11800, 6151 11753, 6148 11800, 6148 11753
Survey Unit 15 6151 11753, 6151 11745, 6148 11753, 6148 11745
Survey Unit 16 6151 11745, 6151 11737, 6148 11745, 6148 11742, 6149 11742, 6149 11737
Survey Unit 17 6151 11737, 6151 11730, 6150 11737, 6150 11735, 6148 11735, 6148 11730
Survey Unit 18 6148 11800, 6148 11753, 6145 11800, 6145 11753
Survey Unit 19 6148 11753, 6148 11745, 6145 11753, 6145 11747, 6147 11747, 6147 11745
Survey Unit 20 6148 11745, 6148 11742, 6149 11742, 6149 11737, 6150 11737, 6150 11735, 6148 11735, 6148 11737,6147 11737, 6147 11745
Survey Unit 21 6147 11747, 6147 11737, 6145 11747, 6145 11737
Survey Unit 22 6148 11737, 6148 11730, 6145 11737, 6145 11730
Survey Unit 23 6145 11800, 6145 11750, 6143 11800, 6143 11750
Survey Unit 24 6145 11750, 6145 11740, 6143 11750, 6143 11740
Survey Unit 25 6145 11740, 6145 11730, 6143 11740, 6143 11730
Survey Unit 26 6200 11730, 6200 11726, 6156 11730, 6156 11726
Survey Unit 27 6200 11726, 6200 11720, 6156 11726, 6156 11723, 6158 11723, 6158 11720
Survey Unit 28 6200 11720, 6200 11715, 6158 11720, 6158 11723, 6156 11723, 6156 11717, 6158 11717, 6158 11715
Survey Unit 29 6200 11715, 6200 11712, 6158 11715, 6158 11717, 6155 11717, 6155 11712
Survey Unit 30 6156 11730, 6156 11723, 6153 11730, 6153 11723
Survey Unit 31 6156 11723, 6156 11717, 6152.5 11723, 6152.5 11717
Survey Unit 32 6155 11717, 6155 11712, 6151 11717, 6151 11712
Survey Unit 33 6153 11730, 6153 11723, 6151 11730, 6151 11723, 6151.5 11723, 6151.5 11717, 6152.5 11717, 6152.5 11723
Survey Unit 34 6151 11730, 6151 11723, 6148 11730, 6148 11723
Survey Unit 35 6151.5 11723, 6151.5 11717, 6148 11723, 6148 11717
Survey Unit 36 6148 11730, 6148 11724, 6145 11730, 6145 11724
Survey Unit 37 6148 11724, 6148 11717, 6145 11724, 6145 11717

Falaise Lake

Survey Unit 1 6130 11630, 6130 11623, 6127 11630, 6127 11623
Survey Unit 2 6130 11623, 6130 11610, thence along N shore of Falaise Lake to 6127 11623
Survey Unit 3 --
Survey Unit 4 6127 11610, thence along S shore of Falaise Lake to latitude 6130, then to 6130 11600, 6127 11600, 6127 11605, 6126 11605, 6126 11610
Survey Unit 5 6127 11630, 6127 11623, thence along shore to 6126.5 11620, 6125 11620, 6125 11630
Survey Unit 6 6126.5 11620, thence along shore to 6127 11610, 6125 11610, 6125 11620
Survey Unit 7 6127 11605, 6127 11600, 6123.5 11600 6123.5 11603, thence N along cutline to latitude 6124, then diagonally to 6126 11605
Survey Unit 8 6125 11630, 6125 11625, 6121 11630, 6121 11625
Survey Unit 9 6125 11625, 6125 11616, 6123 11625, 6123 11616
Survey Unit 10 6125 11616 6125 11610, 6121 11610, 6121 11613, 6123 11613, 6123 11616
Survey Unit 11 6126 11610, 6126 11605, diagonally to 6124 11603, along cutline to 6123.5 11603, 6123.5 11610
Survey Unit 12 6123 11625, 6123 11619, 6120, 11619, 6120 11625
Survey Unit 13 6123 11619, 6123 11613, 6122 11613, 6122 11619
Survey Unit 14 6123.5 11610, 6123.5 11602.5, thence around bay to longitude 11600, thence to 6121 11600, 6121 11610
Survey Unit 15 6121 11630, 6121 11625, 6117.5 11625, 6117.5, 11623, thence to the lakeshore along longitude 11623 and W to 6118 11630
Survey Unit 16 6120 11625, 6120 11613, thence S to the surveyed cutline at ca. 6118 11613, thence W along that cutline to the lakeshore at ca. 6118 11620, 6117.5 11620, 6117.5 11625
Survey Unit 17 6121 11613 6121 11607, to the cutline at ca. 6118 11607, thence W along the cutline top ca. 6118 11613
Survey Unit 18 6121 11607, 6121 11600, thence S to the cutline at ca. 6118 11600, thence W along the cutline to ca. 6118 11607
Survey Unit 19 6117.5 11623, 6117.5 11620, then N to the shore of Boulogne Lake, thence E along the cutline to ca. 6118 11612, thence S to the shore of Great Slave Lake and W along the shoreline to longitude 11623 Survey
Unit 20 6118 11612, thence E along the cutline to 611811605, 6115 11605, thence W to the lakeshore and N and W along the shore to longitude 11612
Survey Unit 21 6118 11605, thence E along the cutline to longitude 11600, 6115 11600, 6115 11605
Survey Unit 22 --
Survey Unit 23 6140 11630, 6140 11622, 6137.5 11630, 6137.5 11622
Survey Unit 24 6140 11622, 6140 11615, 6137.5 11622, 6137.5 11615
Survey Unit 25 6140 11615, 6140 11608, 6137.5 11615, 6137.5 11608
Survey Unit 26 6140 11608, 6140 11600, 6138 11608, 6138 11600
Survey Unit 27 6137.5 11630, 6137.5 11622, 6135 11630, 6135 11622
Survey Unit 28 6137.5 11622, 6137.5 11615, 6135 11622, 6135 11615

Survey Unit 29 6137.5 11615, 6137.5 11608, 6135 11615, 6135 11608
Survey Unit 30 6135 11607, 6135 11605, 6136 11605, 6136 11602, 6137 11602, 6137 11600, 6133 11600, 6133 11602, 6134 11602, 6134 11607
Survey Unit 31 6135 11630, 6135 11625, 6133 11625, 6133 11620, 6130 11630, 6130 11622, 6132 11622, 6132 11630
Survey Unit 32 6135 11625, 6135 11618, 6132 11618, 6132 11620, 6133 11620, 6133 11625
Survey Unit 33 6135 11618, 6135 11611, 6132 11611, 6132 11618
Survey Unit 34 6135 11611, 6135 11607, 6134 11607, 6134 11602, 6133 11602, 6133 11600, 6132 11600, 6132 11611
Survey Unit 35 6132 11630, 6132 11620, 6130 11622, 6130 11630
Survey Unit 36 6132 11620, 6132 11611, 6130 11611, 6130 11620
Survey Unit 37 6132 11611, 6132 11600, 6130 11600, 6130 11611
Survey Unit 38 6138 11608, 6138 11600, 6135 11608, 6136 11605, 6136 11605, 6136 11602, 6137 11602, 6137 11600

APPENDIX B. ANIMALS SEEN ON RECONNAISSANCE

Mills Lake

SURVEY UNIT	ANIMALS SEEN	LAT	LONG
Block 1	2 moose	6141	11757
Block 2	-	-	-
Block 3	-	-	-
Block 4	4 bison	6140	11741
Block 5	3 moose	6142	11733
Block 6	2 moose	6139	11735
Block 7	-	-	-
Block 8	-	-	-
Block 9	1 bull moose	6138	11754
Block 10	-	-	-
Block 11	1 moose	6136	11751
Block 12	2 moose (cow-calf)	6136	11744
Block 13	1 moose	6134	11732
Block 14	-	-	-
Block 15	-	-	-
Block 16	-	-	-
Block 17	-	-	-
Block 18	1 moose	6132	11753
Block 19	3 bison	6131	11734
	3 bison	6132	11757
	1 bison	6133	11757
Block 20	2 bison	6131	11804
	6 bison	6129	11803
Block 21	-	-	-
Block 22	-	-	-
Block 23	-	-	-
Block 24	1 wolf	6133	11827
Block 25	-	-	-
Block 26	1 bison	6136	11818
	1 bull moose	6135	11822
Block 27	1 moose	6136	11814
Block 28	2 bison	6134	11804
	3 bison	6134	11801
Block 29	-	-	-
Block 30	4 bison	-	-
	1 bison	-	-
Block 31	1 bison	6139	11819
Block 32	3 moose (boundary w/31)	6139	11823

Block 33	-	-	-
Block 34	2 moose	6141	11820
Block 35	1 moose	6143	11814
Block 36	-	-	-

Mink Lake

SURVEY UNIT	ANIMALS SEEN	LAT	LONG
Block 1	4 bull moose + 1 cow	6158	11754
Block 2	1 moose	6157	11753
	2 bull moose	6158	11751
Block 3	-	-	-
Block 4	-	-	-
Block 5	1 moose	6155	11758
	2 moose	6156	11756
Block 6	1 bull moose	6157	11753
Block 7	2 bison	6156	11740
Block 8	64 bison	6154	11733
	10 bison	6154	11736
	4 bison	6155	11734
	1 bison	6155	11733
Block 9	2 moose (cow-calf)	6153	11752
Block 10	2 moose (cow-calf)	6152	11751
Block 11	--		
Block 12	6 bison	6152	11739
	14 bison	6153	11735
	[1 moose on island, off transect @ 6153 11737]		
Block 13	5 bison	6152	11734
	2 moose	6152	11733
	43 bison	6152	11736
Block 14	-	-	-
Block 15	-	-	-
Block 16	-	-	-
Block 17	3 bison	6150	11733
	2 moose (bull and cow)	6150	11732
	2 bison	-	-
Block 18	-	-	-
Block 19	3 moose	6145	11748
Block 20	-	-	-
Block 21	-	-	-
Block 22	2 bison	6146	11735
	uncounted herd of bison	6146	11735
Block 23	4 bison	6144	11752
Block 24	2 moose	6144	11742
Block 25	-	-	-
Block 26	-	-	-
Block 27	-	-	-
Block 28	-	-	-
Block 29	-	-	-
Block 30	2 moose (cow-calf)	6153	11723

Block 31	5 moose (+ 3 more?)	6154	11720
Block 32	3 moose	6151	11712
Block 33	2 moose	6152	11723
Block 34	1 moose	6148	11727
Block 35	2 moose (cow-calf)	6150	11722
Block 36	-	-	-
Block 37	-	-	-

Falaise Lake

SURVEY UNIT	ANIMALS SEEN	LAT	LONG
Block 1	6 caribou	-	-
Block 2	4 bison	-	-
	14 bison	-	-
	67 bison	6127	11618
	17 bison	-	-
	1 bison	-	-
	14 bison	-	-
	18 bison	-	-
	1 bison	-	-
	30 bison	-	-
	1 bison	-	-
	11 bison	-	-
	2 bison	-	-
Block 4	2 bison	-	-
	2 bison	-	-
Block 5	1 bison	-	-
	1 bison	-	-
Block 6	2 bison	6125	11613
Block 7	1 cow moose	6124	11602
	1 bull moose	612330	11603
Block 8	-	-	-
Block 9	-	-	-
Block 10	-	-	-
Block 11	-	-	-
Block 12	1 bull moose	612050	1162234
Block 13	-	-	-
Block 14	2 bison	6122	11605
	4 bison	6122	11607
Block 15	1 bull moose	6120	11629
Block 16	5 bison	-	-
	73 bison	-	-
	ca. 175 bison	-	-
	ca. 100 bison	-	-
	45 bison	-	-
	31 bison	-	-
	22 bison	-	-
	55 bison	-	-
	1 bison	-	-
Block 17	1 bison	6120	11610
	3 moose	6120	11609
	1 cow moose	6119	11612
Block 18	-	-	-
Block 19	-	-	-

Block 20	-	-	-
Block 21	1 bison	6115	11605
Block 22	-	-	-
Block 23	6 bison	6137	11625
Block 24	-	-	-
Block 25	2 moose (cow-calf)	6137	11609
Block 26	3 bull moose	6137	11600
	3 bison	6138	11603
	1 bull moose	6137	11606

Falaise Lake (continued)

Block 27	-	-	-
Block 28	2 caribou	6135	11616
Block 29	-	-	-
Block 30	-	-	-
Block 31	-	-	-
Block 32	-	-	-
Block 33	-	-	-
Block 34	-	-	-
Block 35	-	-	-
Block 36	-	-	-
Block 37	43 bison	6130	11602
	14 bison	6130	11603
	10 bison	6130	11603
	2 bison	6130	11606
	30 bison	6130	11606
	5 bison	6130	11609
	6 bison	6130	11609
Block 38	2 bison	6137	11604
	3 bull moose	613757	11600
	1 moose	613659	1160009
	2 cow moose	613640	1160015

APPENDIX C. OBSERVATIONS MADE DURING MILLS LAKE SURVEY

SU	YR♂	MED♂	LGE♂	♀	♀ 1/ CALF	♀ 2/ CALF	TOTAL MOOSE	BISON	LAT	LONG
2L		-					0		-	
5H			3				3		6140	11737
8L			1				1		6137	11754
8L					1		2		6138	11749
8L					1		2		6137	11750
8L			1				1		6137	11750
8L		1					1		6137	11750
8L					1		2		6136	11745
10M				1			1		6134	11738
11H				1			1		6136	11745
11H				1			1		6136	11745
11H			1				1		6135	11746
11H				1			1		6134	11747
14L					1		2		6133.0	11732.1
14L								12	6130.3	11730.2
16L							0		-	-
17L				1			1		6150	11746
17L					1		2		6130	11747
17L				1			1		-	-
17L				1			1		-	-
18H		1	1				2		6131.3	11753.0
25L						1	3		-	-
25L					1		2		6137	11829
27M		3	1				4		6135	11815
27M					1		2		6136	11819
27M				1			1		6136	11808
31L			1				1		6138	11821
31L				2			2		6138	11829
31L		3		2			5		6138	11821
31L				1			1		6139	11822
31L				1			1		6139	11815
31L					1		2		6139	11814
31L		1	1				2		6140	11822
31L	1						1		6140	11818

Mills Lake (continued)

SU	YR♂	MED♂	LGE♂	♀	♀ 1/ CALF	♀ 2/ CALF	TOTAL MOOSE	BISON	LAT	LONG
33L							0		-	-
34H	1				1		3		6141	11821
34H	1						1		6143	11815
35M				1			1		6141	11813
35M				1			1		6142	11816

APPENDIX D. OBSERVATIONS MADE DURING MINK LAKE SURVEY

SU	YR♂	MED♂	LGE♂	♀	♀ 1/ CALF	♀ 2/ CALF	TOTAL MOOSE	BISON	LAT	LONG
1H					1		2		6200.0	11758.3
1H	1			2			3		6159.3	11757.2
1H				1			1		6159.3	11757.5
1H	1	2	1				4		6159.2	11758.6
1H					1		2		6158.9	11754.4
1H			1		1		3		6158.1	11757.2
1H			1				1		6157.2	11755.0
3M			1				1		6157.9	11746.0
3M				1			1		6157.6	11738.5
3M					1		2		6158.2	11744.9
3M				1			1		6158.6	11744.9
4L	1				1		3		6157.6	11735.8
4L								2	6157.5	11730.0
5H							0		-	-
6M							0		-	-
16L							0		-	-
20L			3				3		6148.9	11741.1
20L								2	6147.5	11736.5
20L								1	6148.2	11736.8
20L								1	6149.0	11737.3
20L								1	6149.8	11736.5
28M					1		2		6159.1	11715.8
28M					1		2		6157.8	11717.3
28M								1	6156	11717
28M					1		2		6159.9	11717.6
29M	1						1		-	-
29M		1	1				2		-	-
29M			2				2		-	-
32H			1				1		6155.0	11717.0
32H			4				4		6153.5	11716.0
32H					1		2		6153.4	11715.5
32H				1			1		6151.5	11716.2
32H	1			1			2		6151.1	11716.2
32H					1		2		6153.1	11714.4
32H			1				1		6154.4	11713.8
32H					1		2		6151.4	11712.8
32H			1				1		6154.4	11713.4

Mink Lake (continued)

SU	YR♂	MED♂	LGE♂	♀	♀ 1/ CALF	♀ 2/ CALF	TOTAL MOOSE	BISON	LAT	LONG
34H		1				1	4		6150.0	11723
34H								1	6150.0	11727.6
34H								1	6150.4	11729.9
34H				1			1		6149.3	11726.7
34H		1	2				3		6149.3	11726.8
34H		1			1		3		6148.9	11723.0
34H								1	6148.1	11729.8
35H								2	6151.4	11717.9
35H					1		2		6151.4	11719.0
35H		1		2			3		6150.8	11719.4
35H				1			1		6149.9	11714.7
35H		1			1		3		6148.2	11720.3
35H				1			1		6149.3	11720.3
35H					1		2		6150.4	11720.6
35H			1				1		6151.2	11721.5
35H			1				1		6151.1	11721.8
35H			1		1		3		6150.7	11722.5
37M					2		4		6147.5	11717.9
37M			1		1		3		6146.0	11722.0
37M					1		2		6146.1	11722.4
37M			2	1			3		6147.4	11723.7
37M			1				1		6147.5	11724.0